Coastal Protection and Restoration Authority
450 Laurel Street, Baton Rouge, LA 70804 | coastal@la.gov | www.coastal.la.gov

2017 Coastal Master Plan

Appendix C – Modeling

Attachment C3-8

Mottled Duck, Anas fulvigula, Habitat Suitability Index Model

Report: Version I

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Prepared By: Paul Leberg (University of Louisiana at Lafayette)

Coastal Protection and Restoration Authority

This document was prepared in support of the 2017 Coastal Master Plan being prepared by the Coastal Protection and Restoration Authority (CPRA). The CPRA was established by the Louisiana Legislature in response to Hurricanes Katrina and Rita through Act 8 of the First Extraordinary Session of 2005. Act 8 of the First Extraordinary Session of 2005 expanded the membership, duties and responsibilities of the CPRA and charged the new Authority to develop and implement a comprehensive coastal protection plan, consisting of a Master Plan (revised every 5 years) and annual plans. The CPRA's mandate is to develop, implement and enforce a comprehensive coastal protection and restoration Master Plan.

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- The Water Institute of the Gulf - Ehab Meselhe, Alaina Grace, and Denise Reed
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Executive Summary

The 2012 Coastal Master Plan utilized Habitat Suitability Indices (HSIs) to evaluate potential project effects on wildlife species. Even though HSIs quantify habitat condition, which may not directly correlate to species abundance, they remain a practical and tractable way to assess changes in habitat quality from various restoration actions. As part of the legislatively mandated 5-year update to the 2012 plan, the wildlife habitat suitability indices were updated and revised using literature and existing field data where available. The outcome of these efforts resulted in improved, or in some cases entirely new suitability indices. This report describes the development of the habitat suitability indices for mottled duck, *Anas fulvigula,* for use in the 2017 Coastal Master Plan modeling effort.

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List of Abbreviations

CPRA	Coastal Protection and Restoration Authority
HSI	Habitat Suitability Index
LDWF	Louisiana Department of Wildlife and Fisheries
SAV	Submerged Aquatic Vegetation
SI	Suitability Index
USFWS	United States Fish and Wildlife Service
wd	Water depth

1.0 Species Profile

The mottled duck (*Anas fulvigula*) differs from the other duck species modeled for the 2017 Coastal Master Plan in that it is a year-round resident of coastal Louisiana and the other states bordering the northern Gulf of Mexico. The species is largely non migratory although there may be seasonal movements in response to resource availability (Bielefeld et al., 2010). The species is threatened by degradation of coastal freshwater habitats (Bielefeld et al., 2010). Alligators are a major source of natural mortality for hens following reproduction (Bielefeld and Cox, 2006). In Florida, the genetic integrity of the species is threatened by hybridization with mallards (*Anas platyrhynchos*).

Reproductive patterns in this species are summarized in Bielefeld et al. (2010). Pair formation occurs in November, and reproduction takes place in the spring and summer (Figure 1). Males provide no parental care; females incubate eggs and brood the hatchlings. The clutch size varies between 8 and 12 eggs and incubation takes approximately 26 days. Mottled ducks reproduce at one year of age.

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Nesting and Care of Hatchlings												
Foraging												

Figure 1. Seasonal activities of mottled ducks in Louisiana. White cells indicate the life stage/activity is generally not present, light grey cells indicate the life stage is at moderate abundance, dark grey cells indicate times of highest life stage activity.

Mottled ducks primarily utilize freshwater marsh habitats in Louisiana, with intermediate and brackish marsh utilized to a lesser extent (Bolduc, 2002; Bolduc and Afton, 2004) (Table 1). In the chenier plain of Texas, mottled ducks showed a strong preference for freshwater sites (Haukos et al., 2010). There appears to be little or no use of saline marshes (Bielefeld et al., 2010); however, such habitats are used in coastal Texas if *Ruppia maritima,* which is a food source, is present (Haukos et al., 2010). Zwank et al. (1989) reported no use of forested wetlands by mottled ducks in Louisiana. Surveys of wintering ducks by the Louisiana Department of Wildlife and Fisheries (LDWF) give conflicting results of mottled duck habitat use. For example, east of the Mississippi River mottled duck densities are highest in freshwater marsh; whereas west of the river freshwater marsh has the lowest densities.

Based on work in Texas wetlands (White, 1975), mottled ducks most often used sites with intermediate levels of emergent vegetation coverage (32 -70%). Use decreases in marsh with greater or lesser coverage of emergent vegetation (Table 1). Haukos et al. (2010) failed to observe this relationship; however, this might have been due to differences in sampling approaches in the two studies. Mottled ducks in Texas (Haukos et al., 2010) did not use areas of marsh with tall vegetation (> 1.3 m). Greatest use occurred when vegetation was <0.6 m.

The species requires unsubmerged habitat for nesting (Bielefeld et al., 2010). In Louisiana, hens often use levees as nest sites (Walters et al., 2001; Pierluissi et al., 2010). Vegetated dredge spoil islands in the Atchafalaya Delta may be some of the most important mottled duck habitat in Louisiana (Holbrook et al., 2000). In Florida, the species will often nest in suburban areas when other habitats are lacking (Varner et al., 2013). Areas with abundant trees are not suitable nest habitat (Rorabaugh and Zwank, 1983; Walters et al., 2001). Rorabaugh and Zwank (1983) indicated that the value of a site declined with tree and shrub cover and declined to zero at coverage greater than 70%. In Louisiana, Holbrook et al. (2000) and Walters et al. (2001) found that while mottled ducks avoided trees they did not avoid shrubs as nesting habitat.

Bolduc (2002) examined the relationships between adult habitat use and water depth in coastal Louisiana. Based on this analysis, it was determined that water depths between 10 and 34 cm are preferred. However, investigations of brood foraging habitat (Rorabaugh and Zwank, 1983; Bielefeld et al., 2010) suggest that water depths down to 1 cm are important to ducklings. The species is observed using water as deep as 54 cm as well as water as shallow as 2 cm. As broods require shallow water to forage, nesting habitat has to be within 3 km of water that is <15 cm deep (summarized in Bielefeld et al., 2010). Based on the work of Durham and Afton (2006), shorter distances to brood foraging sites probably enhance the value of nesting habitat.

Young mottled ducks have a reduced tolerance for saltwater intake compared to adults, thus broods require areas with low salinity to forage (Rorabaugh and Zwank, 1983). Moorman et al. (1991) found salinities >9 ppt would be detrimental to ducklings. Rorabaugh and Zwank (1983) indicated that low salinity, shallow water had to be with 3 km of a site to make it useful as nesting habitat. This value is much greater than the maximum distance of nests from water (713 m) observed in southwest Louisiana (Durham and Afton, 2006).

Table 1. Characteristics associated with mottled duck habitat used in the HSI model.

Characteristic	Optimum	Suboptimum
Vegetation Type[1]	Freshwater Marsh	Intermediate followed by Brackish and Saline marsh (with SAV)
Percent Emergent Vegetation[2]	32-70%	Marsh with less or more complete emergent cover
Water depth[3]	1 – 34 cm	34 to 54 cm
Average salinity during the months of April-July[4]	≤ 9 ppt	> 9 ppt

[1] Based on Bolduc, 2002; Bolduc and Afton, 2004; and Haukos et al., 2010.
[2] Based on White, 1975.
[3] Based on Rorabaugh and Zwank, 1983; Bolduc, 2002; and Bolduc and Afton, 2004. Shallower depths are utilized by ducklings as foraging habitat and are thus most important in the summer.
[4] Based on Moorman et al., 1991.

2.0 Approach

An HSI model was developed for mottled duck by Rorabaugh and Zwank (1983), and subsequently revised for use in the 2012 Coastal Master Plan (Nyman et al., 2013). A decision was made to restructure the 2012 HSI model after the author found flaws with some of the assumptions made. In the current effort, there is no attempt to focus on nesting habitat, although a variable was added to give greater weight to habitats necessary for rearing young.

There are four variables in the current model. Model variables were selected as a result of a literature review, updated for the current effort, which attempted to identify the important variables associated with habitat used by mottled ducks. In addition, estimates of mottled duck densities in different marsh types were obtained from the Louisiana Department of Wildlife and Fisheries (Larry Reynolds, unpublished data).

Habitat characteristics were assigned values between 0 and 1, with a value of 1 being assigned to the most preferred habitat state (United States Fish and Wildlife Service [USFWS], 1981). Quantitative measures of habitat use for an environmental variable were divided by the value for the variable state that had the highest value. This placed all the values of the variable on a scale from 0 to 1. Additional procedures are discussed for the individual variables. The HSI index values were obtained by taking the geometric means of the suitability indices of the individual variables (USFWS, 1981).

To validate the model, outputs from the 2012 Master Plan models, generated with the software EverView, were obtained for sites where the author had made field observations suggesting the species was common, uncommon, or absent. Outputs were applied to the habitat suitability model, and the HSI estimates were compared to the authors' field observations. In general, there was good correspondence between observations of mottled duck abundance and the HSI estimates. However, this exercise indicated that cells with very high and low values of emergent vegetation, or with very shallow water might support more mottled ducks than the initial model had suggested, leading to slight modifications of the model.

3.0 Habitat Suitability Index Model for Mottled Duck

The habitat suitability index (HSI) for mottled duck in a model cell is the geometric mean of four suitability index (SI) variables, each scaled from 0–1, where 1 is the most suitable. The resulting HSI will be a value between 0 and 1. Cells with values near 1 should be the most suitable for the species whereas cells with values near 0 are unsuitable.

$HSI = (SI_1 \times SI_2 \times SI_3 \times SI_4)^{1/4}$

Where:
SI_1 = Dominant emergent vegetation (V_1)

SI_2 = Proportion of emergent vegetation (V_2)

SI_3 = Average annual water depth (V_3)

SI_4 = Average salinity during the months of April-July (V_4).

3.1 Applicability of the Model

This model applies to both juvenile and adult mottled ducks in coastal Louisiana.

3.2 Response and Input Variables

V_1 – Proportion of emergent vegetation and associated open water.

V_1 is the proportion of a cell that is wetland and associated open water. This variable should be calculated yearly. When there is no emergent vegetation in a cell, the cell should be assigned to one of following vegetation types based on average annual salinity:

Fresh Attached Marsh if salinity is < 1.5 ppt
Intermediate Marsh if salinity is $\geq$ 1.5 and < 4.5 ppt
Brackish Marsh if salinity is $\geq$ 4.5 and < 9.5 ppt
Saline Marsh if salinity is $\geq$ 9.5 ppt.

These thresholds are taken from Appendix D-4 of the 2012 Coastal Master Plan Report (Visser et al., 2012).
$SI_1 = (1.0 * V_{1a}) + (1.0 * V_{1b}) + (0.67 * V_{1c}) + (0.55 * V_{1d}) + (0.23 * V_{1e}) + (0.0 * V_{1f}) + (0.0 * V_{1g})$

When:

V_{1a} = Proportion Fresh Attached Marsh (Weight = 1.0)

V_{1b} = Proportion Fresh Floating Marsh (Weight = 1.0)

V_{1c} = Proportion Intermediate Marsh (Weight = 0.67)

V_{1d} = Proportion Brackish Marsh (Weight = 0.55)

V_{1e} = Proportion Saline Marsh (Weight = 0.23)

V_{1f} = Proportion Swamp Forest (Weight = 0.0)

V_{1g} = Proportion Bottomland Forest (Weight = 0.0)

Rationale: Mottled duck abundance has been shown to vary among marsh types in Louisiana (Bolduc, 2002; LDWF aerial surveys of wintering waterfowl). For marsh types, this index is based on an average of the relative use based on density estimates from Bolduc (2002), relative habitat use based on radio-telemetry (Davis, 2012), density estimates based on air-boat surveys (Davis, 2012), and density estimates based on LDWF waterfowl surveys (unpublished data). There was not much resolution beyond freshwater marsh, intermediate marsh and brackish marsh in these surveys; LDWF and Davis (2012) collected data on saline marshes but Bolduc (2002) did not. For each study, the relative value of a vegetation type as mottled duck habitat was determined by dividing the measure of use for that vegetation type by the highest value of use observed in any vegetation type. This process set the value of the habitat type with the most mottled duck use to 1.0 (= optimal habitat), scaling the other use values by the highest value. The scaled values from the four data sets were then averaged for each habitat. These averages were again rescaled, so that the highest averaged value had a value of one. Based on the average of the relative use of marsh habitats obtained from these studies, mottled ducks occur most frequently in freshwater marsh and proportionately less frequently in the other marsh habitat types (intermediate marsh, brackish marsh, and saline marsh) (Figure 2). A value of 0 was set for bottomland forest and swamp forest. Zwank et al. (1989) reported no use of forested wetlands by mottled ducks in Louisiana and Haukos et al. (2010) reported an avoidance of tall vegetation; therefore forested habitats were assigned values of 0.

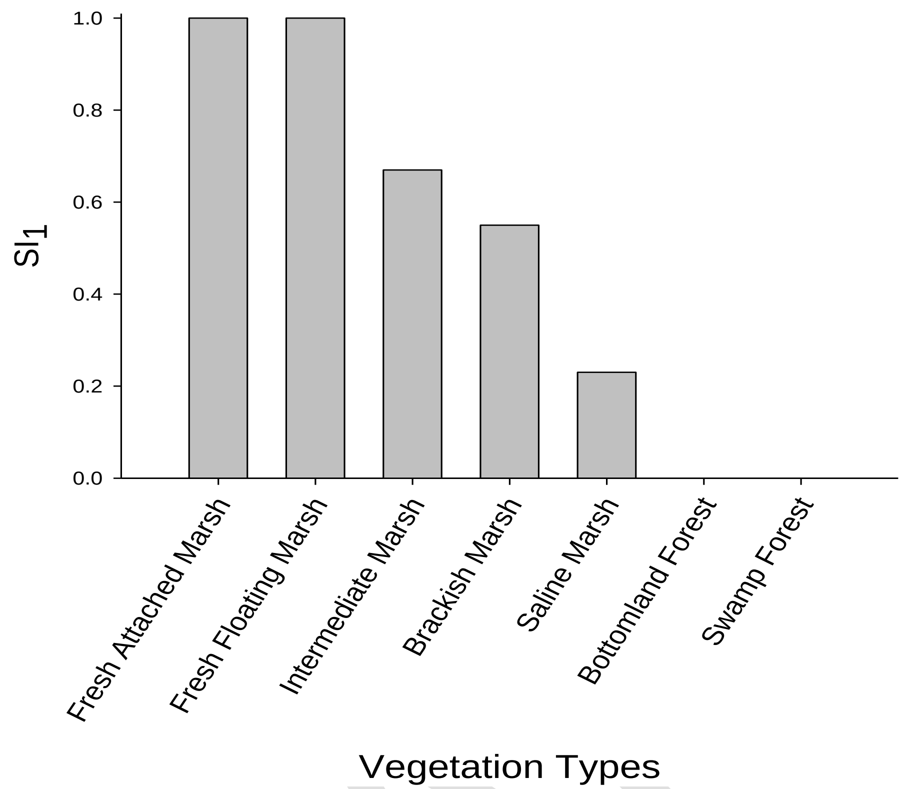

Figure 2. Relative values (SI_1) of different types of emergent vegetation types as habitat for mottled ducks. Because cells can have varying combinations of different categories, the figure represents SI values for cells comprised entirely of the category represented on the horizontal axis.

V_2: Proportion of cell that is emergent marsh

Variable 2 (V_2) is the proportion of the cell that is emergent marsh. Emergent marsh is defined as the sum of the proportions of fresh attached marsh, fresh floating marsh, intermediate marsh, brackish marsh, and saline marsh in a cell. This variable should be calculated yearly.

$$SI_2 = \begin{cases} (2.81 * V_2) + 0.1 & \text{for } V_2 < 0.32 \\ 1.0 & \text{for } 0.32 \leq V_2 \leq 0.70 \\ (-3.0 * V_2) + 3.1 & \text{for } V_2 > 0.70 \end{cases}$$

Rationale: Mottled duck habitat use has been shown to vary with the proportion of emergent marsh based on research at a site in coastal Texas (White, 1975). This relationship is based on White (1975) who found that mottled ducks most often used sites where the proportion of emergent marsh was between 0.32 and 0.70. This range of proportion of emergent vegetation was assigned an index of 1 (= optimal habitat) (Figure 3). As emergent vegetation occupied more than 70% or less than 32% of an area, observations of mottled ducks decreased, with ducks not using areas where there was no emergent vegetation or no open water. The change of the index value from optimal values was converted into a linear function to de-emphasize the influence of effects of small changes in the environmental variable on the index value. Under this definition, cells with 100% swamp forest, bottomland forest, or open water would be assigned a value of 0.10. There is little suggestion in the literature that mottled ducks typically use such habitats (Bielefeld et al. 2010).

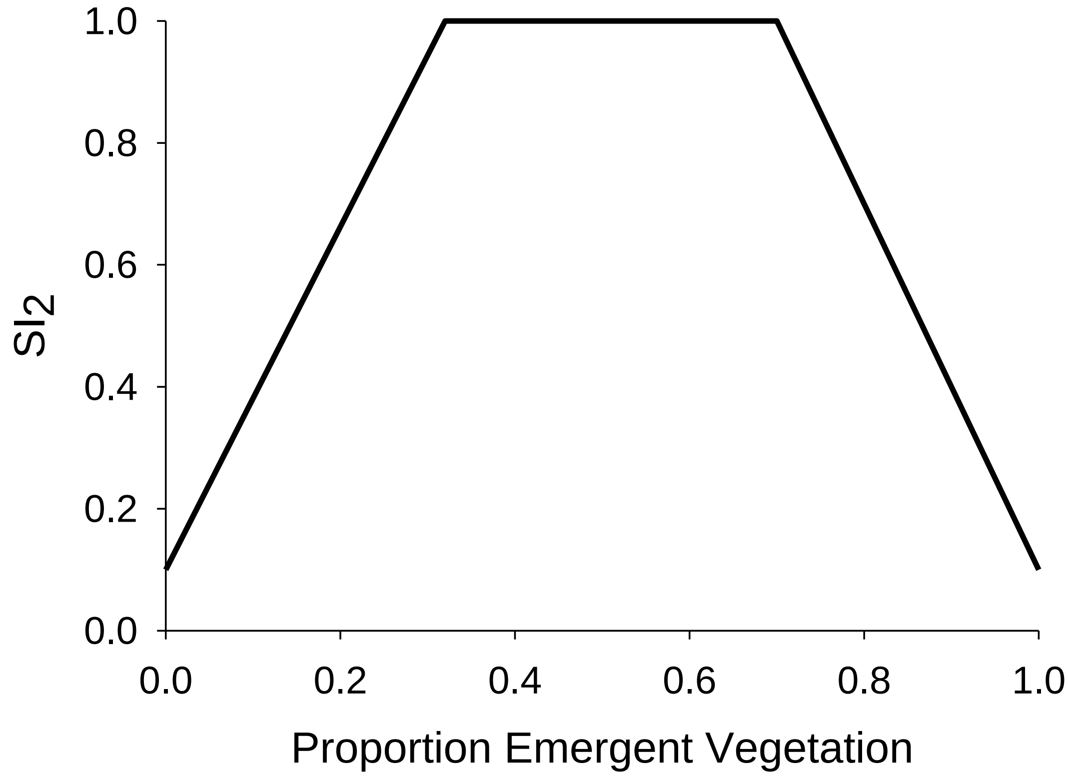

Figure 3. Relative values (SI_2) of sites as habitat for mottled duck as a function of the proportion of the cell that is emergent marsh vegetation.

V_3: Average water depth

Variable 3 (V_3) is the proportion of pixels in a cell where the average annual water depth (in cm) provides suitable foraging habitat. This variable should be calculated once per year.

$SI_3 = (0.6 * V_3a) + (1.00 * V_3b) + (0.83 * V_3c) + (0.57 * V_3d) + (0.35 * V_3e) + (0.22 * V_3f) + (0.09 * V_3g) + (0.0 * V_3h)$

When:

V_3a = the proportion of pixels in a cell where the average water depth (wd) for the year is $0 \leq$ depth $\leqq 8$ cm (weight = 0.6)

V_3b = the proportion of pixels in a cell where the average water depth (wd) for the year is $8 <$ wd ≤ 30 cm (weight = 1.00)

V_3c = the proportion of pixels in a cell where the average water depth (wd) for the year is $30 <$ wd ≤ 36 cm (weight = 0.83)

V_3d = the proportion of pixels in a cell where the average water depth (wd) for the year is $36 <$ wd ≤ 42 cm (weight = 0.57)

V_3e = the proportion of pixels in a cell where the average water depth (wd) for the year is $42 <$ wd ≤ 46 cm (weight = 0.35)

V_3f = the proportion of pixels in a cell where the average water depth (wd) for the year is $46 <$ wd ≤ 50 cm (weight = 0.22)

V_3g = the proportion of pixels in a cell where the average water depth (wd) for the year is 50 < wd ≤ 56 cm (weight = 0.09)

V_3h the proportion of pixels in a cell where the average water depth (wd) for the year is 56 cm < wd (weight = 0.0)

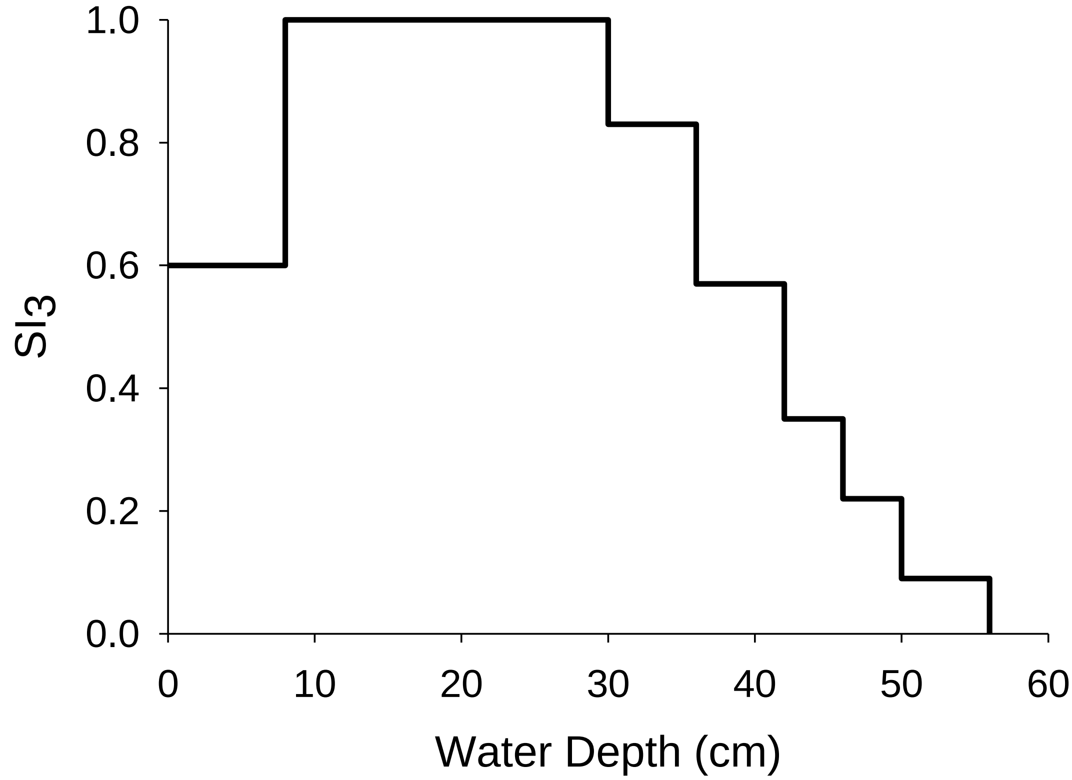

Figure 4. Relative values (SI_3) of sites as habitat for mottled ducks based on water depth. Because cells can have varying combinations of different categories, the figure represents SI values for cells comprised entirely of the category listed on the horizontal axis.

Rationale: Mottled duck habitat use has been shown to vary by water depth (Bolduc, 2002; Bolduc and Afton, 2004). This index is based on the nonparametric regressions of habitat use in coastal Louisiana developed by Bolduc (2002). Depth was divided into classes and the most utilized class was assigned an index of 1.0 (= optimal water depth). Depths that were used to a lesser extent received proportionally lower values. To accommodate brood foraging habitat (Rorabaugh and Zwank, 1983; Bielefeld et al., 2010) water depths down to 8 cm were assigned a value of 1, and lesser depths were assigned a value of 0.6 (Figure 4), even though Bolduc's models predicted that adults use these water depths less frequently than deeper water. Since the mottled duck is a year-around resident, average annual water depth for each pixel is used in the index.

V_4: Average salinity of cell during brood rearing

Variable 4 (V_4) is the average salinity of a cell (in ppt) for the months of April – July. This variable should be calculated yearly.

$SI_4 =$ 1.0 for $V_4 \leq 9.0$ ppt
$(-0.11 * V_4) + 2.0$ for $V_4 > 9.0$ ppt

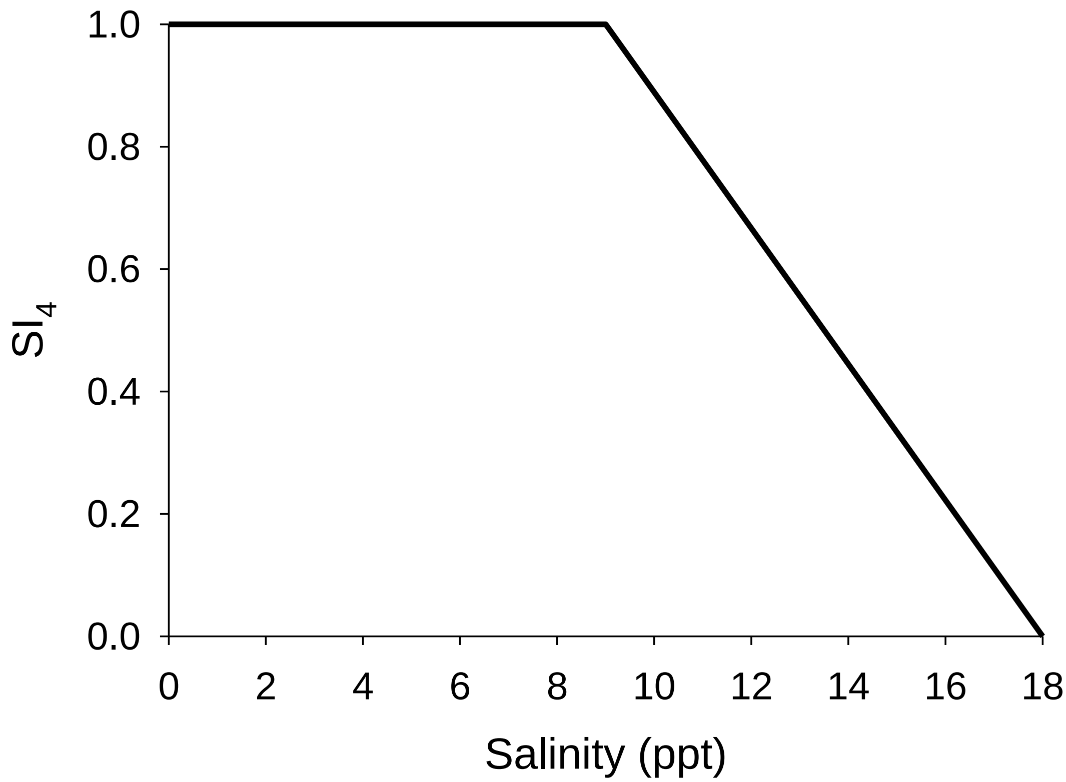

Figure 5. Relative values (SI_4) of sites as habitat for mottled duck as a function of the average salinity (ppt) for the period between April and July.

Rationale: High salinities have been shown to increase mortality and decrease growth rates of mottled duck ducklings in Louisiana (Moorman et al., 1991). Moorman et al. (1991) found that most mottled duck juveniles experience decreased survival and growth rates above 9 ppt. Mortality was 100% at 18 ppt. Thus, SI_4 was assigned a value of 1 (= optimal salinity) when average salinities were ≤ 9 ppt (Figure 5). The value of this index decreased to 0, when average salinities were >18 ppt. This index is based on salinities between April and July as this is when juvenile mottled ducks would be present in Louisiana's coastal marshes.

This relationship is based on the effects of salinity on juvenile mottled ducks. There is good evidence that adults can tolerate higher salinities. However, since habitat for rearing ducklings is more restricted than the habitat adults can use for foraging, it is assumed that changes in the abundance of low salinity habitats will have a greater effect on mottled duck populations than will changes in other habitats.

4.0 Model Verification and Future Improvements

To help ensure the distributions and patterns of HSI scores across were realistic relative to current knowledge of the distribution of mottled duckl, a verification exercise was conducted. In order to generate HSI scores across the coast, the HSI models were run using calibrated and validated

ICM spin-up data to produce a single value per ICM grid cell. Given the nature of a coastwide model, the ICM spin-up data may not reflect 'real-world' conditions in all areas of the coast. For example, some areas known to have wetland vegetation were classified as non-wetland habitat resulting in low HSI scores when high scores would otherwise be expected. In these instances, no improvements could be made to the HSI as these issues reside in other ICM subroutines (i.e., vegetation). As a result, the accuracy of the verification exercise is contingent on these inconsistencies.

In general, and with the exception noted above, cells known to have high concentrations of mottled duck had the highest HSI values, and cells with where few teal are observed had low HSI values. Although there was general agreement between model outputs and known distributions of the species, several improvements are suggested.

This HSI could have been improved by modeling the nesting habitat for the species. However, much of nesting of this species occurs on non-wetland habitats immediately adjacent to wetlands or on small patches of elevated habitat in more contiguous wetland habitats. The spatial/temporal resolution of the Master Plan model inputs is not on an appropriate scale to estimate changes in nesting habitat. Increasing the fine scale resolution of the hydrology model might make identification of suitable nesting habitats possible. Furthermore, if the model included land use changes in the upland areas immediately adjacent to coastal wetlands, it might make an attempt to estimate the suitability of cells as mottled duck nesting habitat more meaningful.

Other improvements would result from better data on habitat use by the species. There are no good data on waterfowl use of floating fresh marsh relative to other habitat types. For our purposes, we assigned this habitat type the same value as emergent fresh marsh; however, the relative value of floating fresh marsh to waterfowl needs investigation.

Additionally, there is a possibility that an interaction exists between water depth and salinity based on Bolduc's (2002) work in impounded and un-impounded wetlands. More study is needed to assess the effects of water depth in different habitats on habitat use.

Much of the available data on habitat use is based on observations of adult birds. Studies of the characteristics of brood habitat would be of benefit to understanding the effects of habitat change on the species. For example, the relationship between emergent vegetation and habitat suitability is based on a study of adult mottled ducks from a freshwater site in Texas. Studies from Louisiana are needed to test the assumption that the modeled relationship holds for Louisiana wetlands, wetlands of different salinities, or habitats used by females with ducklings.

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